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The Automation of Nowcast Model Assessment Processes

by Leelinda P Dawson, John W Raby, and Jeffrey A Smith

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1. Introduction

Battlefield weather forecasting has transitioned from a human forecaster located in theater to the usage of computerized systems that include Numerical Weather Prediction (NWP) models, with the human forecaster being far from the area of interest.¹ Thus, the accuracy of these models is becoming more important on the battlefield. The US Army Research Laboratory (ARL) modelers are using their own high-resolution configuration of the Weather Research and Forecasting (WRF)² model, referred to as Weather Running Estimate–Nowcast (WRE-N),³ to produce and improve the accuracy of weather forecasts.

Nowcast model assessment involves applying the model verification techniques to generate error statistics to characterize model performance and provide insight on how to improve the accuracy of the forecasts produced by the ARL’s nowcast model, WRE-N.⁴ ARL has implemented Model Evaluation Tools (MET) developed by the National Center for Atmospheric Research (NCAR) that provide multiple tools to characterize domain-level model performance. MET was developed at NCAR through a grant from the United States Air Force 557th Weather Wing (formerly the Air Force Weather Agency), where NCAR is sponsored by the United States National Science Foundation. During the assessment process, the model’s output and the weather observations (or ground truth) are used by the MET software. MET compares the weather observation data with the WRE-N model forecast output to calculate various error statistics.

The 2 main goals of generating error statistics are to, first, provide guidance to the warfighters about the accuracy of the forecast models and, secondly, provide modelers with the information needed to understand the model errors and how their algorithm changes might mitigate these errors. In doing so, the model output and error statistics from the original model can be quantitatively compared to the model output and error statistics from the upgraded model that includes the modeler’s algorithm changes. By performing this comparison, the modeler can easily determine which module or physics algorithm is affecting the model’s forecast in a way that reduces the size of the errors. Thus, developing an improved forecast model will, in turn, provide better forecast data for ingesting into decision support tools that can be later transitioned to the Warfighter on the battlefield.

In this document, a process for automating the running of the MET statistical verification tool, Point-Stat (version 4.1),⁵ was implemented to generate domain-level error statistics for the ARL modelers who are actively trying to improve the WRE-N model forecasts. The Point-Stat tool calculates traditional, grid-to-point error statistics by calculating the forecast minus observation differences. The

statistics derived from these differences are output as statistical text files.⁶ The previous implementation of the Point-Stat tool required the model forecast and observation data to be processed for one run configuration at a time; that is, only one model run, domain, hour, and case study date could be set for each run. This process was time-consuming when multiple configurations were required by the user. Also, each run of the tool overwrote the data from the previous run. The automation process of implementing the Point-Stat tool, referred to as Point-Stat Automation (PSA), was needed to generate error statistics efficiently for multiple model runs, domains, hours, and dates. In addition, this process provided a controlled, automatic data structure, which uniquely identified each dataset of error statistics that will be easily used in future data analysis by ARL modelers.

2. Development Environment

The automation of Point-Stat processes (i.e., PSA) was developed using Python 3.5.* Python was selected because it is easy to use, widely used for scripting, and satisfies all the requirements to automate the implementation of the Point-Stat tool. In addition, the Weather Running Estimate-Nowcast_Real Time (WREN_RT) system currently in development is implemented in Python. WREN_RT will be a system that will automate real-time WRE-N model simulations, collect and quality control check weather observations for assimilation and verification, and produce user-friendly graphical output of weather forecasts as well as verification statistics, such as the error statistics output generated from PSA. The ultimate goal will be to integrate WREN_RT with the automation Point-Stat process and scripts described in this document, so that error statistics can be generated “on the fly” after a WRF or WRE-N model run is completed. Initial implementation is envisioned to perform this task over domains centered near White Sands Missile Range, New Mexico, where the Meteorological Sensor Array (MSA) will be located. The MSA will provide additional, high-resolution observations for the verification of the WRE-N model. Having both PSA and WREN_RT in Python will bring consistency to the whole automation process and make integration easier in the future.

3. Description of Scripts

The automation process of Point-Stat involved the development of the following 2 Python scripts: *read_configFiles.py* and *runPointStat.py*. The first script, *read_configFiles.py*, mainly handles the reading and parsing of each configuration parameter set in the PSA configuration file, *ps_auto_config*, and the WREN_RT

*Python is a registered trademark of Python Software Foundation. <http://www.python.org>.

configuration file, *wren.config* (see Section 5). All the configuration values are stored into arrays and passed as arguments to the second script, *runPointStat.py*, which handles the implementation of running the Point-Stat tool using the configuration values. To run the script, the user must set the configuration values in *ps_auto_config* and *wren_rt.config* files to satisfy their unique data requirements. Then, the user executes the following command, “python runPointStat.py”, to automatically calculate the domain-level error statistics. During the script’s execution, the script makes repetitive command calls to the Point-Stat tool in order to generate all the error statistics output based on the user’s configuration specified in the *ps_auto_config* file.

4. Data Structure

The PSA scripts use input and output data that are organized in a particular structure. The input data specified by the scripts consist of forecast data and observation data (see Section 6), as well as Point-Stat domain-level, PSA, and WREN_RT configuration files (see Section 5). The standard data structure for the PSA process is depicted in Fig. 1. The forecast data, observation data, and Point-Stat domain-level configuration files are the input data required to run the Point-Stat tool (i.e., data in the <forecast_dir>, <obs_dir>, and <config_dir> directories, respectively, as shown in Fig. 1), while the PSA and WREN_RT configuration files are required input data by the PSA scripts (i.e., *ps_auto_config* and *wren.config*, respectively, as shown in Fig. 1). The Point-Stat configuration files specify the types of statistical output to be generated. The output data consist of the Point-Stat error statistics and PSA log file (i.e., data in the <output_dir> and <log_dir>, respectively, as shown in Fig. 1). The error statistics output consists of the calculated error statistics that are generated from the Point-Stat tool (see Section 9). The Point-Stat log file is generated by the Point-Stat tool during execution and displays log and debug information (see Section 8). The PSA log file is similar to the Point-Stat log file, but it, instead, contains log and debug information relating to the PSA execution.

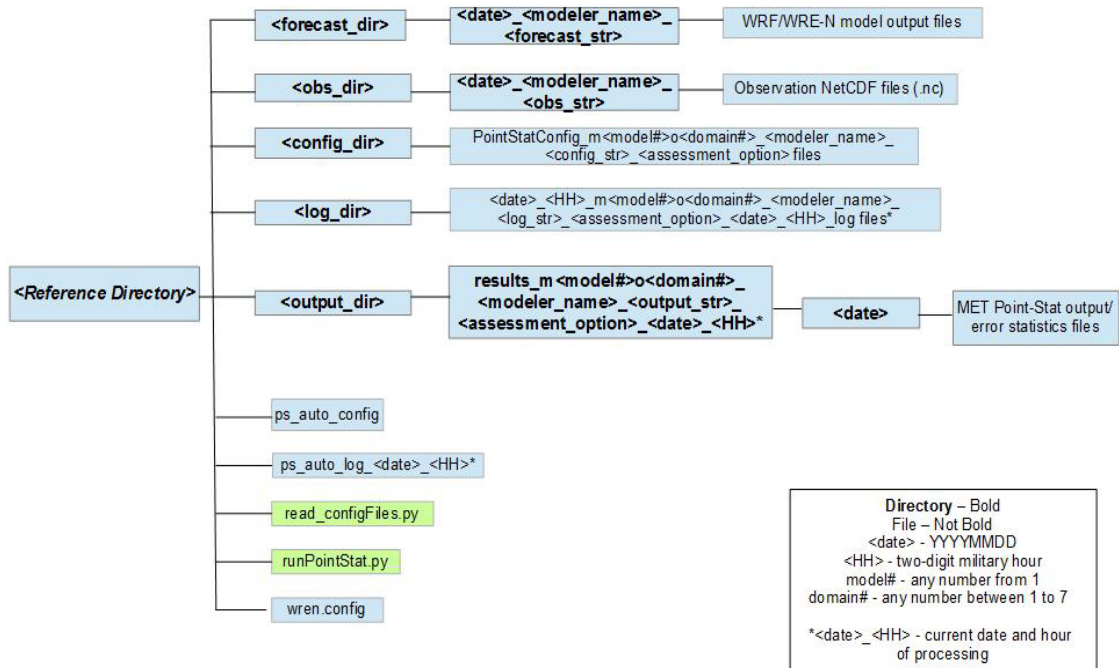


Fig. 1 Standard data structure of PSA

5. Configuration Files

The PSA configuration file, *ps_auto_config*, controls the process and output of the PSA scripts. All the values set in the PSA configuration file determine how the scripts use the Point-Stat tool to generate error statistics. A description of all these configuration values can be found in Table 1. A template of *ps_auto_config* is provided along with the PSA scripts and the user can modify it according to their specific needs. An example *ps_auto_config* file and its corresponding data structure is shown in Figs. 2 and 3, respectively.

The WREN_RT configuration file, *wren.config*, contains configuration settings or properties from the WRE-N model runs. Currently, the PSA scripts map only the configuration parameter, *<horizontal_grid_spacing_m>*, in the file to retrieve values of the model grid resolutions. For example, as shown in Fig. 4, m1, m2, and m3 would be mapped to 27000.0 (27 km), 9000.0 m (9 km), and 3000.0 (3 km), respectively. Note that once the integration with the WREN_RT system is complete, this file will be auto-generated or transferred by the system, so that error statistics can be developed “on-the-fly” after a WRE-N model run.

Table 1 PSA configuration values in *ps_auto_config*

| Configuration Parameter | Description |
|-------------------------|--|
| <i>model</i> | m1, m2, m3, m4...m<n>, or ALL One or more model runs separated by a comma “,” or All model runs. There can be any number of model runs denoted by m<n> starting at 1. The value of “ALL” represents all model runs that are available. It will search the forecast data directory (i.e., <forecast_dir>) and determine which model runs are available for processing. |
| <i>domain</i> | D1 (o1), D2 (o2), D3 (o3), D4 (o4), D5 (o5), D6 (o6), D7 (o7), or ALL One or more domains separated by a comma “,” or All domains. The maximum number of domains is 7. The value of “ALL” represents all domains that are available. It will search the forecast data directory (i.e., <forecast_dir>) and determine which domains are available for processing. |
| <i>hours</i> | HH:MM:SS or ALL One or more hours or times separated by a comma “,” or All hours. The HH:MM:SS specifies the format of the time listed as hours, minutes, and seconds respectively in Coordinated Universal Time (UTC), such as 12:00:00. The value of “ALL” represents all hours that are available. It will search the forecast data directory (i.e., <forecast_dir>) and determine which hours are available for processing. |
| <i>date</i> | YYYYMMDD One or more case study dates separated by a comma “,”. The YYYYMMDD specifies the format of the case study date listed as year, month, and day respectively, such as 20160801 for August 01, 2016. |
| <i>modeler_name</i> | The name of modeler One or more modeler’s names separated by a comma “,”. Note that if using multiple modelers for one run, the configuration parameters above should be exactly the same. Otherwise, it is advised to create different configuration files for each modeler. |
| <i>forecast_dir</i> | Directory path where the WRF forecast input data resides in relation to the PSA scripts The scripts searches for the forecast data using the following naming convention: <forecast_dir>/<date> <modeler_name> <forecast_str> |
| <i>forecast_str</i> | User-defined string to assist in identifying the forecast data |
| <i>obs_dir</i> | Directory path where the point observation input data (i.e., NetCDF files) resides in relation to the PSA scripts The scripts searches for the observation data using the following naming convention: <obs_dir>/<date> <modeler_name> <obs_str> |
| <i>obs_str</i> | User-defined string to assist in identifying the point observation data |
| <i>config_dir</i> | Directory path where the Point-Stat configuration files reside in relation to the PSA scripts The scripts search for the configuration files using the following naming convention: |

Table 1 PSA configuration values in *ps_auto_config* (continued)

| | |
|---------------------------------|--|
| | <code><config_dir>/PointStatConfig_m<model#>o<domain#>_<modeler_name>_<config_str>_<assessment_option></code> |
| <i>config_str</i> | User-defined string to assist in identifying the configuration files |
| <i>output_dir</i> | <p>Directory path where the MET Point-Stat output or error statistics data will reside in relation to the PSA scripts</p> <p>The scripts create the output directory using the following naming convention: <code><output_dir>/results_m<model#>o<domain#>_<modeler_name>_<output_str>_<assessment_option>_<YYYYMMDD>_<HH>/<date></code></p> <p>Note that <YYYYMMDD> <HH> represents the current date and military hour of processing.</p> |
| <i>output_str</i> | User-defined string to assist in identifying the MET Point-Stat output data |
| <i>log_dir</i> | <p>Directory path where the MET Point-Stat log files will reside in relation to the PSA scripts</p> <p>The scripts creates the log directory using the following naming convention: <code><log_dir>/<date>_<hour>_m<model#>o<domain#>_<modeler_name>_<log_str>_<assessment_option>_<YYYYMMDD>_<HH>_log</code></p> <p>Note that <YYYYMMDD> <HH> represents the current date and military hour of processing.</p> |
| <i>log_str</i> | User-defined string to assist in identifying the MET Point-Stat log files |
| <i>log_verbosity</i> | <p>Verbosity level in Point-Stat log files</p> <p>Setting the verbosity to 0 will make the tool run with no log messages, while increasing the verbosity above 1 will increase the amount of logging.</p> |
| <i>execute_option</i> | <p>Execution option for the PSA scripts to run manually or on a scheduled basis</p> <p>To run the scripts manually, set the option to 0.</p> <p>*To run on a scheduled basis, set the option to 1 and the case study date will be set to the next day of case study date. The script will run on a scheduled basis based on data availability. Note that the next day of the case study date is used because the verification or assessment cannot be done until the wall clock time is past the end of the time period of the model forecasts.</p> |
| <i>debug</i> | <p>Debug option to display debug messages during PSA execution</p> <p>To turn the debug mode off, set the option to 0. No debug information is displayed on the screen during the execution of the scripts.</p> <p>To turn the debug mode on, set the option to 1. When the debug mode is turned on, the script will display the debug information on the screen during the execution of the scripts.</p> <p>Note that the Point-Stat auto log file, <i>ps_auto_log</i>, will always contain debug and log information regardless whether the debug mode is on or off.</p> |
| <i>assessment_option</i> | <p>Assessment option to perform Domain Dependent Assessment (DDA) or Resolution Dependent Assessment (RDA)</p> <p>To set DDA, set the option to 0 (e.g. m1o1, m2o2, m3o3)</p> <p>To set RDA, set the option to 1 (e.g. m1o3, m2o3, m3o3)</p> |
| | *This is a future capability and will be available once the integration with WREN_RT is complete. |

```

#PS_AUTO_CONFIG Settings
model = ALL
domain = ALL
hours = 12:00:00
date = 20120207
modeler_name = P
forecast_dir = MET_WRFpostprd
forecast_str = test
obs_dir = MET_obs/little_r
obs_str = test
config_dir = MET_PointStat/configs
config_str = test
output_dir = MET_PointStat
output_str = test
log_dir = MET_PointStat/logs
log_str = test
log_verbosity = 5
execute_option = 0
debug = 1
assessment_option=0

```

Fig. 2 An example of PSA configuration file, *ps_auto_config*

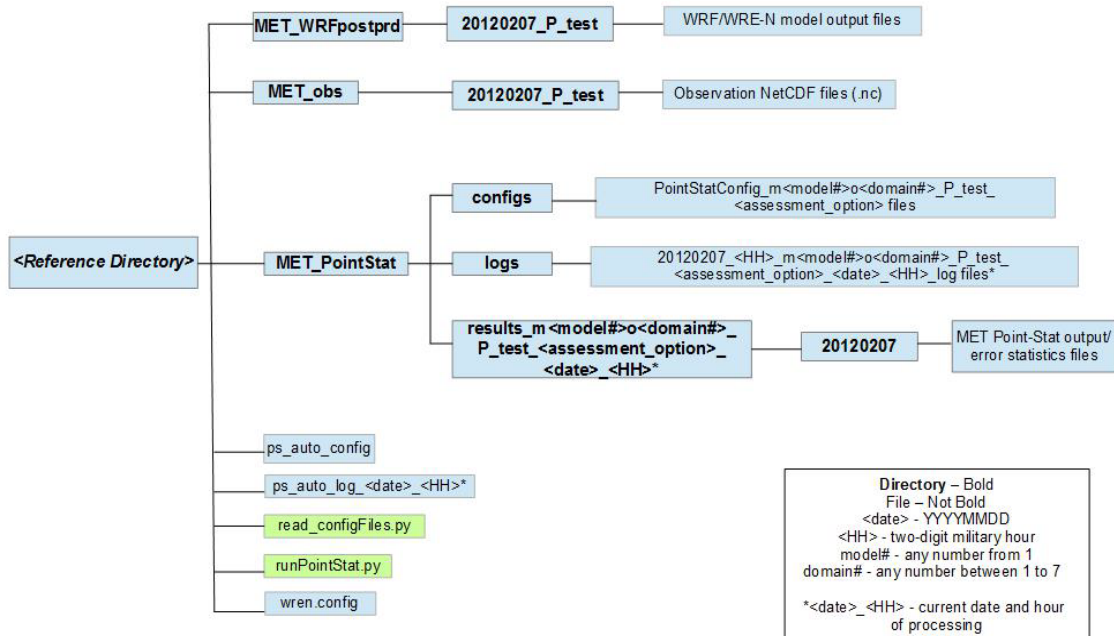


Fig. 3 PSA data structure based on the example configuration file

```
#WREN_RT Settings
horizontal_grid_spacing_m = 27000.0, 9000.0, 3000.0
.
.
.
<Other WREN_RT Property Settings>
```

Fig. 4 An example of WREN_RT configuration file, *wren.config*

6. Forecast and Observation Data

The input data of the PSA scripts are gridded WRF forecast files and point observations required by the Point-Stat tool. The WRF forecast data should be organized by the case study date, modeler's name, and user-defined forecast string, as described in Section 4. The forecast files are grib files created by the National Centers for Environmental Prediction (NCEP) Unified Post Processor (UPP).⁷ There should also be a forecast file corresponding to each case study date, domain, and hour that the user wants to generate error statistics from the Point-Stat tool. For example, if the case study date, domain, and hours are 2016-08-01, D1, and 12:00:00Z to 6:00:00Z (next day), respectively, then there will be 18 gridded WRF forecast files in the forecast data directory. As stated in Section 5, the location of the forecast data should be set in the *ps_auto_config* file by using the configuration parameter, <forecast_dir>, before executing the PSA scripts. The point observation files are in the MET-specific NetCDF format. Similar to the WRF forecast files, the point observations should be organized by the case study date, modeler's name, and user-defined observation string, as described in Section 4. Note that the PSA scripts use the observation data for the domain currently being assessed or verified, if it is available in the observation data directory. Otherwise, the observation data for the outermost (largest) domain, D1, is used.

7. Domain vs. Resolution Dependent Assessment

The PSA scripts can perform the following 2 types of assessments: Domain Dependent Assessment (DDA) and Resolution Dependent Assessment (RDA). This is set in the configuration file, *ps_auto_config*, by the user through the configuration parameter, <assessment_option>, as described in Table 1.

The PSA scripts use DDA to generate error statistics using Point-Stat for multiple domains, starting from the outermost (largest) domain to the innermost (smallest) domain. The outermost domain is always classified as D1 (o1). The WRE-N model

run output is assessed over its respective domains. For example, if there are 3 domains that are assessed over 3 different model runs, namely 27 km (m1), 9 km (m2), and 3 km (m3), all centered on the same geographical point, then the 27 km (m1), 9 km (m2), and 3 km (m3) will be evaluated over D1 (o1), D2 (o2), and D3 (o3), respectively. The goal would be to assess and calculate error statistics for the 3 model domains to determine how they perform over their respective domains (i.e., m1o1, m2o2, m3o3), as shown in Fig. 5.

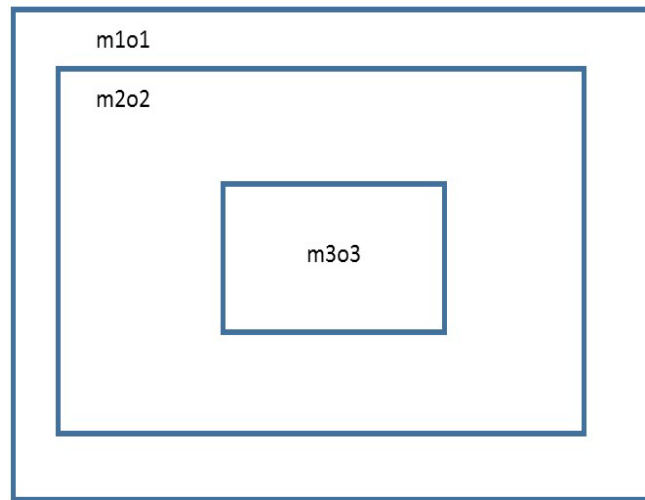


Fig. 5 An example DDA over 3 domains and model runs

The PSA scripts use RDA to generate error statistics using Point-Stat for multiple WRE-N model runs over only the area covered by the innermost domain. This allows the evaluation of any statistical differences among the different model runs over a consistent domain. For RDA, the innermost domain masking files are needed and should be placed in the same directory as the Point-Stat configuration directory specified in *ps_auto_config*. For example, if there are 3 domains that are assessed over 3 different model runs—9 km (m1), 3 km (m2), and 1 km (m3)—all centered on the same geographical point, then 9 km, 3 km, and 1 km will all be evaluated only over the innermost domain, D3 (o3). The goal would be to assess and calculate error statistics on the 3 model runs to determine how they perform over the innermost domain, D3 (i.e., m1o3, m2o3, m3o3).

8. Log File

After the execution of the PSA scripts, a log file is created that contains all the log and debug information pertaining to a particular PSA run. The PSA log file is produced and stored in the same directory, where the PSA scripts are located, as shown in Fig. 1. An example of a PSA log file, *ps_auto_log*, is provided in Fig. 6.

As shown in Fig. 6, a *ps_auto_log* file was created using DDA, one case-study date (i.e., 20120207), 3 domains, 3 model runs, and 1 h (i.e., 12:00:00Z) after a successful run of the PSA scripts. The naming convention of the log file is as follows: *ps_auto_log*_*<YYYYMMDD>*_*<HH>*, where *<YYYYMMDD>* is the current date of processing and *<HH>* is the military hour of processing. The log file is created and stored in the same directory where the PSA script, *runPointStat.py*, is executed. The log file includes various log information, such as the MET version number, assessment option, modeler's name, model number, domain number, hour, case_study_date for each Point-Stat command, and the contents of its command during execution. If there are any error messages from executing the PSA script, the *ps_auto_log* file will include them. If any issues occur relating to the Point-Stat tool, the tool's log file will include them, which will be located in the log directory specified in the *ps_auto_config* file.

```

*** Model Evaluation Tools (METV4.1) ***

Reading the Point-Stat auto configuration file, ps_auto_config...
Reading the WREN_RT configuration file, wren.config...
Setting the configuration parameters...

Running for Domain Dependent Assessment (DDA)...
Forecast Data File: MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d01_2012-02-07_12:00:00
Observation Data File: MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_12:00:00.0000.nc

Created output directory: MET_PointStat/results_m1o1_P_test_DDA_20160726_14/20120207

Running PointStat for P - m1o1, 15.75km res on 20120207 at 12:00:00Z

point_stat MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d01_2012-02-07_12:00:00
MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_12:00:00.0000.nc
MET_PointStat/configs/PointStatConfig_m1o1_P_test_DDA -outdir
MET_PointStat/results_m1o1_P_test_DDA_20160726_14/20120207 -log
MET_PointStat/logs/20120207_12_m1o1_P_test_DDA_20160726_14_log -v 5

Forecast Data File: MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d01_2012-02-07_13:00:00
Observation Data File: MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_13:00:00.0000.nc

Created output directory: MET_PointStat/results_m2o2_P_test_DDA_20160726_14/20120207

Running PointStat for P - m2o2, 5.25km res on 20120207 at 12:00:00Z

point_stat MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d02_2012-02-07_12:00:00
MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_12:00:00.0000.nc
MET_PointStat/configs/PointStatConfig_m2o2_P_test_DDA -outdir
MET_PointStat/results_m2o2_P_test_DDA_20160726_14/20120207 -log
MET_PointStat/logs/20120207_12_m2o2_P_test_DDA_20160726_14_log -v 5

Forecast Data File: MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d02_2012-02-07_13:00:00
Observation Data File: MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_13:00:00.0000.nc

Forecast Data File: MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d03_2012-02-07_12:00:00
Observation Data File: MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_12:00:00.0000.nc

Created output directory: MET_PointStat/results_m3o3_P_test_DDA_20160726_14/20120207

Running PointStat for P - m3o3, 1.75km res on 20120207 at 12:00:00Z

point_stat MET_WRFpostprd/20120207_P_FDDA/131127A_WRFPRS_d03_2012-02-07_12:00:00
MET_obs/little_r/20120207_P_FDDA/qc_obs_used_earth_relative.d01.2012-02-07_12:00:00.0000.nc
MET_PointStat/configs/PointStatConfig_m3o3_P_test_DDA -outdir
MET_PointStat/results_m3o3_P_test_DDA_20160726_14/20120207 -log
MET_PointStat/logs/20120207_12_m3o3_P_test_DDA_20160726_14_log -v 5

```

Fig. 6 An example PSA log file, *ps_auto_log*, using DDA, one case-study date, 3 domains, 3 model runs, and 1 h

9. Output of Error Statistics

After the execution of the PSA scripts, the error statistics results are automatically produced and stored in the output directory specified by the user's configuration in the *ps_auto_config* file, as described in Table 1. The data are organized by model number, domain number, modeler's name, user-defined output string, assessment option, and case study date, as shown in Fig. 1. In addition, the current date and military hour of processing are appended to the end of each results' directories in format of YYYYMMDD_HH. The organization of the data prevents the output files from being overwritten if the scripts are executed again with the same configuration parameters.

The output of the Point-Stat tool consists of multiple American Standard Code for Information Interchange (ASCII)-encoded text files containing a summary of calculated error statistics. For current ARL model assessment purposes, there are 10 sets of text files for each case study's date and hour, where there is one file each representing continuous statistics (CNT), contingency table counts (CTC), contingency table statistics (CTS), forecast, hit, observation rates (FHO), multi-category contingency table counts (MCTC), multi-category contingency table statistics (MCTS), matched pair data (MPR), scalar partial sum (SL1L2), and vector partial sum (VL1L2), and a tenth one for the STAT file (.stat).⁵ The STAT file contains all of the error statistics, while the other files contain identical data, but sorted into files by line type.

The STAT file produced by the Point-Stat tool uses the following naming convention:

point_stat_<prefix>_<HHMMSS>L_<YYYYMMDD>_<HHMMSS>V.stat,

where <prefix> indicates the user-defined string defined in the Point-Stat configuration file, <HHMMSS>L indicates the forecast lead time and <YYYYMMDD_HHMMSS> indicates the forecast valid time.

Similarly, the output of the other text files are named as follows:

point_stat_<prefix>_<HHMMSS>L_<YYYYMMDD>_<HHMMSS>V_<type>
.txt,

where <type> is one of cnt, ctc, cts, fho, mctc, mcts, mpr, sl1l2, or vl1l2 that indicates the line type.⁵ Figure 7 shows an excerpt from the beginning of an FHO error statistics file that was produced by the PSA scripts, point_stat_m1o1P_000000L_20120207_120000V_fho.txt. This is similar to the 8 other individual statistics files that are produced by the Point-Stat tool.

```

VERSION MODEL FCST_LEAD FCST_VALID_BEG FCST_VALID_END OBS_LEAD OBS_VALID_BEG
OBS_VALID_END FCST_VAR FCST_LEV OBS_VAR OBS_LEV OBTYPE VX_MASK INTERP_MTHD INTERP_PNTS
FCST_THRESH OBS_THRESH COV_THRESH ALPHA LINE_TYPE TOTAL_F_RATE H_RATE O_RATE
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P225-
100 TMP P225-100 ADPUPA FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 99 0.00000
0.00000 0.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P225-
100 TMP P225-100 AIRCAR FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 22 0.00000
0.00000 0.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P425-
225 TMP P425-225 ADPUPA FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 153 0.00000
0.00000 0.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P425-
225 TMP P425-225 AIRCAR FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 106 0.00000
0.00000 0.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P625-
425 TMP P625-425 ADPUPA FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 127 0.00000
0.00000 0.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P625-
425 TMP P625-425 AIRCAR FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 55 0.00000
0.00000 0.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P775-
625 TMP P775-625 ADPUPA FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 106 0.27358
0.19811 0.21698
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P775-
625 TMP P775-625 AIRCAR FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 60 0.28333
0.28333 0.31667
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P775-
625 TMP P775-625 ADPSFC FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 119 0.02521
0.00000 0.09244
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P875-
775 TMP P875-775 ADPUPA FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 71 0.85915
0.83099 0.83099
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P875-
775 TMP P875-775 AIRCAR FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 37 1.00000
0.97297 0.97297
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P875-
775 TMP P875-775 ADPSFC FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 513 0.60039
0.42495 0.45224
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P910-
875 TMP P910-875 ADPUPA FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 18 1.00000
1.00000 1.00000
V4.1 9kmPWRE-N 000000 20120207_120000 20120207_120000 000000 20120207_114000 20120207_122000 TMP P910-
875 TMP P910-875 AIRCAR FULL DW_MEAN 4 >273.000 >273.000 NA NA FHO 11 1.00000
1.00000 1.00000

```

Fig. 7 An excerpt of a Point-Stat FHO error statistics file produced by the PSA scripts

10. Conclusion

The scripts that automate the Point-Stat processes (or PSA) were developed to easily generate domain-level error statistics from WRE-N model output data as soon as possible following the model run. They provide an automated, efficient data process that can be used by ARL modelers. This simplifies the modeler's performance of future data analysis and evaluation of WRE-N model improvements.

PSA is one important component of WREN_RT. The long-term goal is to have the real-time WRE-N system (i.e., WREN_RT), that is currently in development, integrated with the Point-Stat automation processes (i.e., PSA) described in this document. When using the WREN_RT system, the following tasks will be completed in an automatic process using the following order:

1. Prepare input data to WRE-N, including collecting the ground-truth observations and performing quality-control checks for the pre-forecast data assimilation period.
2. Run the WRE-N model to generate model forecast data.
3. Create graphical visualization of the model forecast data.
4. Generate error/verification statistics (such as from PSA) after the end of the forecast period, including collecting observations and performing quality checks for the entire model integration period.
5. Populate a data archive containing all of the above for later access by the ARL modelers.

11. References

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List of Symbols, Abbreviations, and Acronyms

| | |
|---------|--|
| ARL | US Army Research Laboratory |
| ASCII | American Standard Code for Information Interchange |
| CNT | Continuous Statistics |
| CTC | Contingency Table Counts |
| CTS | Contingency Table Statistics |
| DDA | Domain Dependent Assessment |
| FHO | Forecast, Hit, Observation |
| MCTC | multi-category contingency table counts |
| MCTS | multi-category contingency table statistics |
| MET | Model Evaluation Tools |
| MPR | matched pair data |
| NCAR | National Center for Atmospheric Research |
| NCEP | National Centers for Environmental Prediction |
| NWP | Numerical Weather Prediction |
| PSA | Point-Stat Automation |
| RDA | Resolution Dependent Assessment |
| SL1L2 | scalar partial sum |
| VL1L2 | vector partial sum |
| WRE-N | Weather Running Estimate-Nowcast |
| WREN_RT | Weather Running Estimate-Nowcast_Real Time |
| WRF | Weather Research and Forecasting |
| UPP | Unified Post Processor |
| UTC | Coordinated Universal Time |

1 DEFENSE TECH INFO CTR
(PDF) DTIC OCA

2 US ARMY RSRCH LAB
(PDF) IMAL HRA MAIL & RECORDS MGMT
RDRL CIO LL TECHL LIB

5 DIR USARL
(PDF) RDRL CIE M
L DAWSON
J RABY
J SMITH
R DUMAIS
B MACCALL